Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **APR 2008**	2. REPORT TYPE	3. DATES COVERED **00-00-2008 to 00-00-2008**

4. TITLE AND SUBTITLE **Advanced Electron Guns and Depressed Collectors Design and Optimization Using the MICHELLE / ANALYST Environment**	5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Naval Research Laboratory,4555 Overlook Avenue SW,Washington,DC,20375**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR’S ACRONYM(S) 11. SPONSOR/MONITOR’S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES
See also ADM002087. Proceedings of the 2008 IEEE International Vacuum Electronic Conference (9th) (IVEC 2008) Held in Monterey, CA on April 22-24, 2008. U.S. Government or Federal Rights License

14. ABSTRACT
see report

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**2**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

23.3: Advanced Electron Guns and Depressed Collectors Design and Optimization Using the MICHELLE / ANALYST Environment*

Ben Held, John DeFord
STAAR Inc., Mequon, WI
ben.held@staarinc.com
Telephone: 262-240-0291, Fax: 262-240-0294

John Petillo, Dimitrios Panagos
SAIC, Billerica, MA

Eric Nelson
LANL, Los Alamos, NM

Baruch Levush, NRL
Washington, DC, USA

Abstract

Next generation vacuum electron devices under development for millimeter and sub-millimeter wavelengths are often characterized by very small features that must be very precisely designed and manufactured for proper tube function and longevity. In this regime the need for automated physics-based optimization to aid the designer in meeting device performance specifications is much more critical than in larger, lower frequency devices where prototyping and experimentation are more readily performed.

Recent work has been done on improving the ability of modeling and design simulation environments to aid the designer in finding optimum configurations. As the simulation tools have improved to enable first-pass design success in some cases, the potential benefits of optimization techniques become even more significant. This paper discusses methods for optimization of electron guns as well as multistage depressed collectors.

Keywords

collector optimization; gun optimization; MICHELLE; ANALYST

Introduction

The ANALYST finite-element design simulation suite [1] is an analysis package which provides comprehensive support for finite-element electromagnetic analysis, including embedded computer-aided design (CAD) software, automated meshing, and both visual and numerical result processing. Analyst includes solvers for electro- and magneto-statics, driven frequency, and eigenmodes, all of which run efficiently on dedicated clusters and parallel computers.

MICHELLE [2],[3] is a two-dimensional (2D) and three-dimensional (3D) steady-state and time-domain electrostatic particle-in-cell (PIC) code. It has been employed successfully by industry, national laboratories, and academia to design a wide variety of devices, including multistage depressed collectors, gridded guns, multi-beam guns, annular-beam guns, sheet-beam guns, beam-transport sections, and ion thrusters.

MICHELLE is available as a component within the ANALYST suite and makes use of the CAD, meshing and analysis tools afforded by ANALYST. We continue to address the issues associated with gun and collector design optimization by the development of optimization tools within the ANALYST suite as well as advanced calculations within the MICHELLE code to support improved optimization metrics. We have found that more sophisticated metric calculations are the key for optimization in complicated cases.

The algorithms currently used in ANALYST for optimization have been developed, exercised, and refined in recent years. These developments continue to concentrate on improving the performance of the optimization capability on complex multi-variate problems common in gun and collector design. In the current work, the optimization algorithms have been developed further and employed on devices with limited ability to have their geometries modified. Reasons for limited geometrical variations include re-use of stock components for cost considerations and reliability, manufacturing constraints, etc.

Optimization Algorithms

The concept of optimizing geometries to meet some design performance objective is a simple one. In fact, there are many cases where the application of such algorithms is straightforward, and design objectives can be met rather easily. In these cases there may be a wide range of parameter space where the design will work within performance and manufacturability specifications. However, we seek algorithms that offer a wider range of applicability so that automated structure optimization can be applied more routinely by design engineers and scientists in the vacuum electronics field. Simple goal functions often produce undesirable affects in realistic applications because they do not sufficiently constrain the design space. Moreover, goal functions that depend on detailed beam behavior can be difficult to evaluate, and trial designs generated by an optimization procedure may produce, for example, beam interception, scalloping, etc., further complicating goal function evaluation.

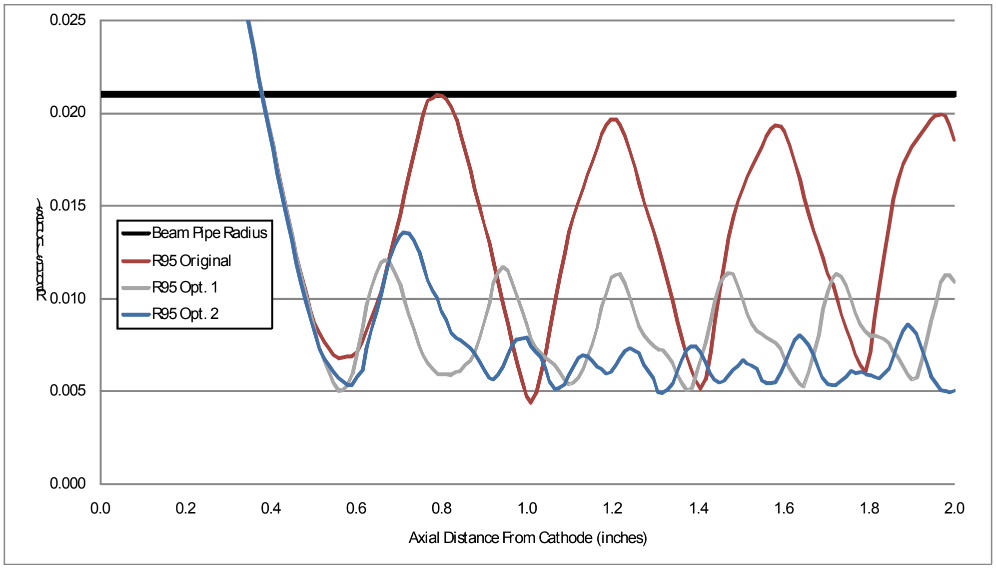

Fig. 1: Solutions obtained by optimizing average beam radius and beam ripple computed using multiple algorithms. Large undesirable beam ripple results from considering only low frequency components of the beam envelope FFT.

Much work has been done to address the metric calculation issue so that the optimization process can properly detect and quantify characteristics such as beam size, beam ripple, etc., allowing the optimization process to smoothly evolve towards an improved solution. As geometric design options become limited, improved quantification through more sophisticated methods of calculating metrics is ever more important. Sometimes the sophistication lies in determining which method of calculation to apply.

Consider the optimization of a simple 2-dimensional Pierce diode. Fig. 1 shows the resulting 95% current-enclosed contour for beam formation and focusing into a PPM stack. The goal is to modify geometric and magnetic field profile parameters to produce a smooth beam with minimal average radius in the beampipe.

Beam ripple does not always follow a repeatable pattern, and robust methods must be used to characterize the ripple before it can be included in a goal function. There are several choices, but we settled initially on using a Fourier transform of the beam envelope to compute both the average radius and ripple amplitude. Instead of minimizing the entire FFT spectrum we only minimized up through the first peak of the spectrum.

Fig. 1 shows an “optimal” result obtained using this strategy. Unconstrained high frequency spectral contributions dominated resulting in a beam with an acceptable average radius but unacceptable ripple amplitude. This result could be improved by considering the entire FFT spectrum.

Results for a subsequent optimization using a goal function in which the ripple amplitude was computed by simply computing the maximum spread in the beam profile beam ripple are also shown in Fig. 1. In this case, this simpler method proved to be a more usable metric, although not as accurate as if the FFT algorithm had known which mode to choose. Since there was a design point with an improved solution available, this method resulted in a much improved solution.

We will present procedures for including important beam characteristics in objective functions, and present results of their application to simple, but difficult to optimize, designs.

References

[1] See www.staarinc.com for documentation on ANALYST.

[2] J. Petillo, et al., "The MICHELLE Three-Dimensional Electron and Collector Modeling Tool: Theory and Design", *IEEE Trans. Plasma Sci.*, **30**, June 2002, pp. 1238-1264.

[3] J. Petillo, et al., “Recent Developments in the MICHELLE 2D/3D Electron Gun and Collector Modeling Code”, *IEEE Trans. Elect. Devices*, **52**, May 2005, pp. 742-748.

* Work supported by NRL and ONR programs.